TWO FELLING TECHNIQUES AND FELLER POSTURES FOR INCREASING THE UTILIZATION OF GMELINA WOOD
(A case study at two timber estates in East Kalimantan)

Sona Suhartana and Yuniawati[1]

ABSTRACT

Felling is an early step in timber utilization process. Efficiency and effectivity of felling technique, tool type and feller posture will affect the whole timber utilization efficiency. This study was carried out at two timber estates in East Kalimantan and intended to see the effect of two felling techniques and feller postures on felling productivity, felling cost, as well as timber utilization efficiency.

Primary data collected in this research included : felling time, volume of felled timber, productivity, felling efficiency, stump height and felling cost. The data was analyzed using split-plot design with factorial pattern.

The result showed that the implementation of lowest possible felling technique (LPFT) increased log production from 14.4 to 17.7%. The lowest stump height left was of the one using LPFT with particular bowed posture in PT. Sumalindo Lestari Jaya I (SLJ I) (4.82 cm)

Keywords : Felling technique, feller postures, cost, productivity, efficiency

I. INTRODUCTION

Tree felling is an early process of logging that transforms a standing tree into logs. The definition of felling is to produce raw materials for wood industry in proper quantity and quality (Direktorat Jenderal Pengusahaan Hutan, 1990). Soenarno and Idris (1990) stated that tree felling is one of the most important logging procedure, because this activity influences wood qualities. Felling can be improved by modifying the technique, bucking and tool mechanization.

In felling activity, it is important to use proper felling technique, using good chainsaw as well as feller postures, so that wood quality is maintained. Efficiency and effectivity in felling technique, tool type, and feller posture will affect the whole timber utilization efficiency.

Gmelina (*Gmelina arborea* Roxb.) is a medium-size tree that can stand 30 - 40 m in height, reveals its stem with smooth surface, and turn grey or light brown in colour. This tree species is originally grown in Pakistan, Srilangka to East Burma. Recently, it is planted in South East Asia, Brazil and Africa. Its wood portion is utilized for light construction material and pulp material that can produce high quality paper. This wood can also be used as materials for floor, music instruments, matches and particleboard. Some parts of this tree are often used for traditional medicine. Its leaves can be used as animal fodder. Gmelina grows in lowland to high land (0-1000 m above sea level), and the best growth is at 0-800 m above sea level. Its corresponding timber is classified into strong class III-IV (Nasution, 1994).

[1] Forest Products Research and Development Center, Bogor

Felling activity needs a good and apropriate planning. The bigger the diameter of the tree, the more difficult the process is. In this case, for simplying and reducing the time of felling activities, the operator needs a good manual or mechanized equipment. Manual felling system uses simple equipment like hand saw, axe and wedge, while mechanized system uses chainsaw. On one side, mechanized felling leads to high-felling productivity, however on the other side, the noise and machine weight influence feller's mental. The non-comfort operator and the relation between worker and machine reduce feller comfort thereby decreasing working efficiency.

The aim of this study was to determine the increase of timber utilization by implementation of two felling techniques (lowest possible felling technique/LPFT and conventional felling technique/CFT) and two feller postures (squatted and bowed).

II. METHODOLOGY

A. Location

This research was conducted in September 2005 at the administration working area of PT. Surya Hutani Jaya (PT. SHJ) with felling site/zone 52C/45, and PT. Sumalindo Lestari Jaya I (PT. SLJ I) with felling site I. PT. SHJ is located in the area of Forest District of Kutai Kartanegara, while PT. SLJ I is in the area of Forest District of Berau, both under East Kalimantan Province.

The topography is mainly sloping between 8-15% (PT. SHJ), 0-25% (PT. SLJ I) with an elevation 100-200 m above sea level (PT. SHJ), 100-250 m above sea level (PT. SLJ I). Further, based on Schmidt and Ferguson's climate classification, the type of research area at PT. SHJ was catagorized as "A" with monthly rainfall of 176 mm. Meanwhile, the corresponding characteristic at PT. SLJ was as "A and B" with 143 and 189 mm monthly rainfall. The soil type is litosol and enceptisol for PT. SHJ, and aluvial and mediteran for PT. SLJ I. In vegetation, the area was dominated by gmelina trees with no buttrees. The tools/equipment used for the logging was STIHL chainsaw of type 038, with 12 HP capacity for felling and bucking operation.

B. Research Object, Material and Tool

The object of this research was felling plot, felling sites of 52C/45 (PT. SHJ) and I (PT. SJL I) which were included in the Company Annual Work Plan 2005. The material and tool used in this research are phi-band measuring meter, stopwatch, compass and chainsaw (Stihl type 038, 12HP).

C. Research Procedures

The stages of this research at each timber estate included :

1. Determining one felling plot for tree felling.
2. Felling of the gmelina trees by combining each of the two techniques (Lowest Possible Felling Technique/LPFT and Conventional Felling Technique/CFT) with each of the postures (bowed and squatted). Further, each of the particular combination as such was

assigned to 10 trees, and this regarded as replication. Therefore, there were 40 trees as the entire number of samples.

3. Parameter measured :
   a. Felling productivity : felling time and volume of timber.
   b. Felling cost : all expenses related to felling activity, which included the expenses of fuel, oil, wages, productivity, depreciation, maintenance, interest, insurance and tax.
   c. Efficiency of timber utilization: tree height, tree diameter at bottom and top portion, and log length.
4. General data of field condition, and secondary data from the company which were taken from company profile and through interview with employees.

For beneficial information in this study, CFT is a felling technique usually used by local operator.Meanwhile, LPFT is a technique that leaves the stump with the height as low as possible.

D. Data Processing

Field data that included felling productivity, timber utilization efficiency and felling cost were presented in the form of tabulation.

1. Felling productivity :

$$FP = \frac{TV}{FT}$$

where : FP = Felling productivity (m^3/hr);
TV = Trees volume (m^3) and FT = Felling time (hour).

2. Timber utilization efficiency :

$$UE = \frac{Vt}{Va} \times 100\%$$

where : UE = Utilization efficiency (%); VT = volume of trees taken (m^3);
Va = volume of trees that is usable (m^3).

3. Felling cost :

$$FC = \frac{Ed + Eis + Eit + Ef + Eo + Em + Ew}{FP} \; ; \quad Ed = \frac{P}{1{,}000 \text{ hours}} \; ;$$

$$Eis = \frac{P \times 0{,}6 \times 3\%}{1{,}000 \text{ hours}} \; ; \quad Eit = \frac{P \times 0{,}6 \times 18\%}{1{,}000 \text{ hours}} \; ; \quad Ef = 0{,}20 \times P \times 0{,}54 \times F\,Pr$$

$$Et = \frac{P \times 0{,}6 \times 2\%}{1{,}000 \text{ hours}} \;;\; Em = 1{,}0 \times Ed \;;\; Eo = 0{,}1 \times Ef$$

where: FC = Felling cost (Rp/m^3); P = Tool price (Rp); Ed = Depreciation expenses (Rp/hr); FP = Felling Productivity (m^3/hr); Eit = Interest expenses (Rp/hr); Et = Tax expenses (Rp/hr); Ef = Fuel expenses (Rp/hr); Fpr = Fuel price (Rp/hr); Eo = Oil expenses (Rp/hr); Em = Maintenance expenses (Rp/hr); and Ew = Wages expenses (Rp/hr);

4. To determine the suggested technique, two felling techniques will be compared on the basis of felling productivity, timber- utilization efficiency, and felling cost, using split-plot design analyses with factorial patterns. As the main plot was felling technique, while as the sub plot was felling posture (Steel and Torrie, 1980).

III. RESULT AND DISCUSSION

A. Felling Productivity

Results of felling productiviy measurement using CFT at two timber estates are presented in Table 1. The table shows the highest productivity using CFT was achieved at PT. SLJ I i.e. 10.254 m^3/hr (bowed posture). This situation might be attributed to the factor of operator ages. At PT. SHJ, most of the operators are about 40 years old, while thoses at PT. SLJ I are about 30 years old. The age factor appeared to significantly affect the operator performance. Suma'mur (1979) stated that operators with age below 25 years tended to be reckless and therefore more susceptible to accident. Meanwhile, the operators with ages over 40 years were on the other hand too old, clumsy, and hence also prone to high accident due to their decreasing physical stamina. Optimum age of the operators turned out to be 30-40 years which relates to physical strength and high-accuracy performance.

Table 1. Data summary on Conventional Felling Technique (CFT) of Gmelina tree

Aspect	V7 cm (m^3)	Felling time, minutes	Productivity, m^3/ hour	*Efficiency,* %	Stump height, cm	Cost, Rp/m^3 felled tree
a. The average of felling productivity, efficiency and cost of conventional with squatted posture (N=10)						
I. PT SHJ						
Rn	0.237-0.694	2.719-5.821	3.823-13.069	80.0-90.9	7.0-9.2	4,745.46-13,803.17
M	0.487	3.175	8.322	84.45	7.55	7,133.48
SD	0.122	0.994	2.723	3.28	0.679	2,909.29
CV	0.251	0.313	0.327	0.039	0.089	0.408
II. PT SLJ I						
Rn	0.315-0.439	2.012-3.112	6.151-13.105	77.3-90.1	6.5-8.5	4,026.67-8,579.01
M	0.353	2.368	9.192	82.3	7.5	6,002.35
SD	0.038	0.354	2.051	3.7	0.64	1,342.33
CV	0.108	0.149	0.223	0.045	0.085	0.224
b. The averages of felling productivity, efficiency and cost of conventional with bowed posture (N=10)						
I. PT SHJ						
Rn	0.159-0.705	2.111-3.970	6.529-11.444	77.2-92.4	6.2-9.1	4,611.10-11,651.47
M	0.449	2.969	9.027	85.58	7.46	6,418.97
SD	0.165	0.582	1.785	4.95	1.031	2,093.15
CV	0.368	0.196	0.198	0.058	0.138	0.326
II. PT SLJ I						
Rn	0.320-0.599	2.051-3.121	6.145-14.423	79.1-90.1	6.1-9.0	3,658.70-8,587.39
M	0.431	2.585	10.254	83.2	7.4	5,492.17
SD	0.078	0.308	2.627	3.96	0.82	1,552.03
CV	0.181	0.119	0.256	0.048	0.111	0.283

Remarks : Rn =Range; M = Mean; SD = Standard Deviation; CV = Coefficient of variation; N = Number of replication (Sampled trees); V7cm =Volume until diameter 7 cm

Operator at PT. SLJ I which are about 30- years old are physically quite stronger, and therefore able to complete the felling operation faster than those at PT. SHJ whose age are about 40 years old, i.e. 2,368 minutes and 2,585 minutes with squatted and bowed postures, respectively. Consequently, operators at PT. SLJ I with bowed postures achieve the highest productivity.

It is shown in Table 2, that implementation of LPFT at PT. SLJ I with bowed postures could achieve the highest productivity (9,181 m^3 per hour). Meanwhile, the corresponding value at PT. SHJ was 8,392 m^3 per hour. Based on felling productivity, further, the felling of gmelina trees using CFT with bowed posture provides the highest productivity (10,254 m^3 per hour). This situation was related to the fact that the technique with bowed posture could provide more comfort and safety to the operators. Further, they would not be quickly exhausted, and therefore require shorter duration to finish their job (i.e. 2,585 minutes).

Table 2. Data summary on Lowest Possible Felling Technique (LPFT) of Gmelina tree

Aspect	V5 cm (m^3)	Felling time, minutes	Productivity, m^3/ hour	Efficiency, %	Stump height, cm	Cost, Rp/m^3 felled tree
a. The averages of felling productivity, efficiency and cost of lowest possiblt felling technique with squatted posture (N=10)						
I. PT SHJ						
Rn	0.171-0.495	2.000-3.111	5.123-9.538	100	4.1-6.1	5,532.55-10,300.51
M	0.328	2.589	7.526	100	5.23	7,350.37
SD	0.097	0.371	1.641	0	0.577	1,782.27
CV	0.296	0.143	0.214	0	0.110	0.242
II. PT SLJ I						
Rn	0.335-0.478	2.125-3.715	6.325-10.124	100	4.2-6.2	5,212.32-8,343.00
M	0.374	2.595	8.222	100	5.21	6,557.14
SD	0.044	0.808	1.250	0	0.547	1,021.77
CV	0.117	0.311	0.152	0	0.105	0.156
b. The averages of felling productivity, efficiency and cost of lowest possible felling technique with bowed posture (N=10)						
I. PT SHJ						
Rn	0.240-0.662	1.568-3.875	5.857-10.456	100	4.1-6.0	5,046.81-9,009.60
M	0.432	3.175	8.392	100	4.84	6,519.67
SD	0.107	0.803	1.647	0	0.699	1,330.79
CV	0.248	0.253	0.196	-	0.144	0.204
II. PT SLJ I4,84						
Rn	0.316-0.463	2.100-3.921	6.123-13.231	100	4.1-6.1	3,988.32-8,618.24
M	0.402	2.743	9.181	100	4.82	6,019.89
SD	0.045	0.674	2.098	0	0.575	1,365.38
CV	0.112	0.246	0.229	-	0.119	0.227

Remarks : Rn = Range; M = Mean; SD = Standard Deviation; CV = Coefficient of variation; N = Number of replication (Sampled trees); V5 cm = Volume until diameter 5 cm

Table 3. Analysis of variance on felling productivity, production cost, and efficiency in the utilization of Gmelina, using split-plot design

Sources of variation	df	Items					
		Felling productivity		Production cost		Efficiency of wood utilization	
		F-calculated	P	F-calculated	P	F-calculated	P
Main plot							
Felling techniques, A	25	1.61	0.0729	1.44	0.1329	24.36	0.0001*
Residual-1	54						
Subplot							
Feller postures, B	1	4.13	0.0469	0.88	0.3523	589.68	0.0001
Interaction, AxB	1	0.13	0.7172	0.26	0.6103	2.95	0.0918
Residual-II	8						
Total	79						
Means		8,763		6.436,752		91,938	
-Unit		m^3/hours		Rp		%	
-CV		21,857		25,917		3,230	
-D0.05		0.8587		747.9		1.3313	

Remarks : * = significant at 5%; P= Probability; D0.05 = Critical value of HSD (honestly significant difference) test at 5%; CV = Coefficient of variation.

The split-plot design analyses (Table 3) for felling productivity revealed the F calculated at 1.61 (probability = 0.0725) to be less significant than at 5% probability. This suggested that both felling techniques (LPFT and CFT) exerted similar productivity.

B. Felling Cost

Based on productivity, purchasing and operation cost using Stihl chainsaw of type 038 for tree felling, the felling cost per m^3 at two timber estates were calculated. The tool purchasing and operational cost were as follows; (1) Price per unit = Rp 4,750,000; (2) Fuel cost = Rp 2,500/litre (September 2005) ; (3) Expected life of tool = 1 year = 1000 hours; (4) Insurance = 3% /years; (5) Interest = 18%/year; (6) Tax = 2%/year; (7) Operator and helper wages = Rp 320,000/day; (8) Work hour per day = 8 hours; (9) Machine power = 12 HP. From the above data, the expenses component could be calculated, as presented in Table 4.

Felling cost of gmelina in each felling technique (LPFT and CFT) and each feller posture (squatted and bowed) could be calculated by dividing the total machine expenses with the corresponding productivity of each technique. The results of felling cost measurement are presented in Tables 1 and 2.

Table 1 indicated that felling cost in CFT with bowed posture at PT. SLJ I (Rp 5,492.17/m^3) was lower than the one at PT. SHJ (Rp 6,418.97/m^3). This situation was caused by the higher productivity as at PT. SLJI (10.254 m^3 per hour).

Table 4. Felling cost component of Gmelina (Rp/hr)

Expense components	Amount (Rp/hr)
- Depreciation expenses	4,275
- Insurance expenses	85.5
- Interest expenses	513
- Taxes expenses	57
- Fuel expenses	3,240
- Oil and grease expenses	324
- Servicing and repairs expenses	4,275
- Wage expenses	40,000
- Total machine expenses	52,769.5

For LPFT with squatted posture at PT. SHJ (Table 2), the felling cost (Rp 7,350.37 per m^3) was higher than the cost at PT. SLJ I (Rp 6,557.14 per m^3). This was brought about by the lower felling productivity at PT. SHJ. Such productivity could still be increased by implementing more proper felling technique and proper feller posture. In this way, the felling cost could be decreased. Further, it turned out that different felling technique (LPFT and CFT) induced no significant effect on felling cost, i.e. F calculated at 1.44 with probability 0.1329 (Table 3), implying that both techniques could achieve similar felling cost. On the other hand, the effect of feller posture was significant on the cost, suggesting that bowed posture could proceed with lower felling cost than squatted posture.

C. Efficiency of timber utilization

Tables 1 and 2 show the averages of timber utilization efficiency (TUE) with the following details: The average TUE values using CFT for PT. SHJ with squatted and bowed postures were consecutively 84.5% and 85.6%. Meanwhile, the corresponding values for PT. SLJ I were 83.2% and 82.3%, respectively. The TUE value using LPFT was 100 percents (as control). Therefore, it suggested that the TUE value using LPFT was still higher (better) than the one using CFT.

Such differences in TUE could be ascribed to the stem length and stump height. Table 5, it reveals that the difference in stem length as used between in CFT and in LPFT at PT. SHJ was +1.054 m, which in volume and percentage was equivalent to consecutively + 0.002 m^3 and +10.4 percent (for squatted posture); and was 1.233 m, equivalent to +0.002 m^3 and +9.6 percent (for bowed posture). Likewise, the corresponding difference at PT. SLJ I was +3.01 m, equivalent to +0.006 m^3 or 15.2% (for squatted posture); and +3.35 m, equivalent to + 0.007 m^3 or 14.7% (for bowed posture). Further, the results of split-plot design analyses revealed that felling techniques and feller postures were both significant on the TUE (Table 3). It suggests that such differences in TUE are due to different felling techniques as well as different feller postures really existed, and further implied as favourable opportunities for the timber estate companies to increase timber utilization through LPFT implementation.

Table 5. Efficiency, stump height and differences in wood length through CFT and LPFT implementation with bowed and squatted postures

	PT SHJ			PT SLJ I		
Felling technique and aspect	Efficiency (%)	Stump height (cm)	Δ t7-t5 (m)	Efficiency (%)	Stump height (cm)	Δ t7-t5 (m)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
a.LPFT-squatted posture						
- Range	100	4.1-6.1	-	100	4.2-6.2	-
- Mean	100	5.23	-	100	5.21	-
- Standard Deviation	0	0.577	-	0	0.547	-
- CV (%)	-	11.0	-	-	10.5	-
b.LPFT-bowed posture						
- Range	100	4.1-6.0	-	100	4.1-6.1	-
- Mean	100	4.84	-	100	4.82	-
- Standard Deviation	0	0.699	-	0	0.575	-
- CV (%)	-	14.4	-	-	11.9	-
c.CFT-squatted posture						
- Range	80.0-90.9	7.0-9.2	1.16-3.38	81.1-90.1	6.5-8.5	1.37-4.55
- Mean	84.45	7.55	2.423	82.3	7.5	3.01
- Standard Deviation	3.28	0.675	1.054	3.7	0.64	1.38
- CV (%)	3.9	8.9	43.5	4.5	8.5	45.8
d.CFT-bowed posture						
- Range	77.2-92.4	6.2-9.1	0.81-5.05	79.1-90.1	6.1-9.0	1.91-6.7
- Mean	85.58	7.46	2.095	83.2	7.4	3.35
- Standard Deviation	4.95	1.031	1.233	3.96	0.82	0.97
- CV (%)	5.8	13.8	0.588	4.8	11.1	29.8

Remarks : Δt7-t5 = Diffferences in wood length with diameter 7 cm and 5 cm; CV = Coefficient of variations.

The company stated that log production per year at PT. SHJ was 30,000 m^3, while at PT. SLJ I was 100,000 m^3, timber selling price was Rp 300,000/m^3 and company benefit was about 20%. The improvement of timber utilization in PT. SHJ were 15.6% (squatted) and 14.4% (bowed), while at PT. SLJ I were 17.7% (squatted) and 16.8% (bowed). In this way, the company will expectedly get added benefit/ advantage per year for PT. SHJ 15.6% x 30,000 m^3 x 20% x Rp 300,000/m^3 = Rp 280.8 million/year (squatted) or 14.4% x 30,000 m^3 x 20% x Rp 300,000/m^3 = Rp 259.2 million/year (bowed). Meanwhile, the added benefit/advantage for PT SLJ I was 17.7% x 100,000 m^3 x 20% x Rp 300,000/m^3 = Rp 1.06 billion/year (squatted) or 16.8% x 100,000 m^3 x 20% x Rp 300,000/m^3 = Rp 1 billion/year (bowed). In this condition, if the company was implementing LPFT, it would have a chance of achieving added benefit with squatted posture.

IV. CONCLUSION

1. The highest felling productivity was the one using conventional felling technique (CFT) with bowed posture in PT. Sumalindo Lestari Jaya I (10,254 m^3/hr).
2. The lowest felling cost was the one using conventional felling technique (CFT) with bowed posture in PT. Sumalindo Lestari Jaya I (Rp 5,492.17/m^3).
3. Implementation of lowest possible felling technique (LPFT) can increase log production by about 14.4-17.7%.
4. Felling operation left the stump with the highest height (i.e. 4.82 cm) when using lowest possible felling technique (LPFT) with bowed posture.

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